

A measurement of the muon charge asymmetry in W boson events

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Abstract. A recent measurement by the D0 Collaboration, of the charge asymmetry of muons in $W \rightarrow \mu\nu$ events is discussed. Using 4.9 fb^{-1} of data collected by the D0 detector, the muon charge asymmetry, $A(\eta)$, where η is the muon pseudorapidity, is measured inclusively and in two bins of muon transverse momentum, p_T^μ . After being corrected for background contamination and detector effects (resolution and acceptance), the data are compared to NLO QCD predictions with CTEQ 6.6 PDFs. For inclusive p_T^μ , reasonable agreement is observed. However, the prediction fails to describe the data in bins of p_T^μ . In most η bins, the data are more precise than the predictions, and will provide tight constraints on future PDFs.

1. Introduction

Studies of W and Z boson production at hadron colliders, provide valuable insight into the QCD production mechanism. The decay channels, $W \rightarrow l\nu$ and $Z \rightarrow ll$ ($l = e, \mu$), offer colourless final states, whose kinematic distributions probe the parton distribution functions (PDFs) of the colliding hadrons. More precise PDFs will ultimately improve our sensitivity to new physics signals at hadron colliders.

In $p\bar{p}$ collisions, W bosons are mostly produced via the scattering of valence u or d quarks from the proton, with the corresponding isospin partner antiquark from the antiproton. Since $u(\bar{u})$ quarks carry more of the proton(antiproton) momentum than $d(\bar{d})$ quarks, W^+ 's tend to be boosted along the proton direction, and W^- 's along the antiproton direction. This production asymmetry, $A(y)$, is defined as

$$A(y) = \frac{d\sigma(W^+)/dy - d\sigma(W^-)/dy}{d\sigma(W^+)/dy + d\sigma(W^-)/dy} \quad (1)$$

where y is the W boson rapidity. Unfortunately, y , and thus also $A(y)$ are not directly measurable in $W \rightarrow l\nu$ decays, due to the unknown momentum of the neutrino along the beam direction. However, given an additional constraint to the known W boson mass, it is possible to estimate y on a statistical basis, assuming the well understood $V - A$ decay coupling [1]. This analysis technique was adopted by the CDF collaboration in a recent measurement of $A(y)$, with 1 fb^{-1} of data in the electron channel [2].

A directly measurable observable, which is also sensitive to $A(y)$, is the analogous lepton charge asymmetry, $A(\eta)$ defined as

$$A(\eta) = \frac{d\sigma(\mu^+)/d\eta - d\sigma(\mu^-)/d\eta}{d\sigma(\mu^+)/d\eta + d\sigma(\mu^-)/d\eta} \quad (2)$$

where η is the lepton pseudorapidity. $A(\eta)$ is less directly sensitive to the PDFs, since it is a convolution of the production asymmetry with the decay asymmetry of the $V - A$ coupling in the decay vertex; the two of which tend to cancel. However, the production asymmetry dominates at small η and/or large p_T^μ , hence the sensitivity to PDFs is enhanced by further binning in p_T^μ . The D0 collaboration has measured $A(\eta)$ with 300 pb^{-1} in the muon channel [3], and 700 pb^{-1} in the electron channel [4].

This document describes a measurement of $A(\eta)$ in the muon channel, using 4.9 fb^{-1} of data [5], which supersedes [3].

2. The D0 detector

The D0 detector is detailed in [6]. Here, only the features that are essential to this measurement are described. Closest to the interaction region, an inner tracker covering the region $|\eta| < 3$, and within a 2 T solenoidal magnet determines the momentum and charge of muons. A liquid argon and uranium calorimeter is contained within three separate cryostats; it determines the missing transverse energy of the event, and provides isolation information for muon identification purposes. Finally, a muon spectrometer covering the region $|\eta| < 2$, with wire chambers, and trigger scintillator counters, either side of a 1.8 T toroidal magnet identifies muon candidates. An important feature of the D0 detector, is that both magnet polarities are reversed periodically, such that the analysed data set contains roughly equal luminosities for each of the four combinations. This dramatically reduces the effect of any charge asymmetry in muon reconstruction efficiencies.

3. Event selection

Candidate $W \rightarrow \mu\nu$ events are required to fire a single muon trigger and contain one muon reconstructed in the muon spectrometer, which is also spatially matched to a track in the inner tracker with $p_T > 20 \text{ GeV}$. Timing cuts based on muon scintillator information reject cosmic ray muons. Additionally, the muon candidate must be isolated in the calorimeter and inner tracker in order to reject jets that fake muons, or semi-leptonic decays of hadrons within jets. The missing transverse energy, \cancel{E}_T , must be greater than 20 GeV, consistent with a high transverse momentum neutrino, and the transverse mass, $M_T = \sqrt{2p_T^\mu \cancel{E}_T(1 - \cos\phi)}$, where ϕ is the azimuthal opening angle between the muon and the neutrino, must be greater than 40 GeV.

4. Detector corrections and background subtraction

The measured $A(\eta)$ must be corrected for the following:

- (i) Detector resolution and acceptance,
- (ii) Backgrounds,
- (iii) Charge mis-identification.

In order to determine corrections for detector resolution and acceptance, $W \rightarrow \mu\nu$ signal events are generated using PYTHIA [7], and passed through a detailed GEANT [8] based simulation of the D0 detector, before being overlaid with randomly triggered events from data. The simulation is further corrected for differences compared to data, in muon reconstruction efficiencies and momentum resolution. Systematic uncertainties on the detector corrections are estimated by varying the momentum resolution in the simulation within its uncertainty.

Backgrounds from $W \rightarrow \tau\nu$, $Z \rightarrow \mu\mu$ and $Z \rightarrow \tau\tau$ processes, are simulated in the same way as the signal, and are subtracted from the data. Multijet backgrounds are estimated directly from data. The efficiency for a jet to fake a muon, f , is estimated from a sample of muon candidates which are back-to-back in azimuth with a reconstructed jet, that also fired a jet trigger. The missing transverse energy of the event is required to be less than 10 GeV, in order to suppress

$W \rightarrow \mu\nu$ signal. Systematic uncertainties on f , are estimated by adding requirements that further suppress signal contamination.

The charge mis-identification rate is estimated using $Z \rightarrow \mu\mu$ candidate events, and is found to have negligible effect on the measurement.

5. Results

After CP folding (assuming $A(\eta) = -A(-\eta)$), figure 1 compares the measured $A(\eta)$ with NLO QCD predictions from from RESBOS [9] using CTEQ 6.6 PDFs [10], with QED radiative corrections from PHOTOS [11]. The yellow bands represent the PDF uncertainties on the predictions. For inclusive p_T^μ , the data and prediction agree well. However, the agreement is rather poor once the measurement is split into bins of p_T^μ .

6. Conclusions

The charge asymmetry of muons from from $W \rightarrow \mu\nu$ decays, $A(\eta)$, has been measured using 4.9 fb^{-1} of data collected by the D0 detector. Predictions from NLO QCD with CTEQ 6.6 PDFs are able to describe the data for inclusive muon p_T^μ , but rather poor agreement with the data is observed in bins of p_T^μ . Apart from the highest η bins, the data are more precise than the predictions, and will thus provide tight constraints on future PDFs.

- [1] A. Bodek, Y. Chung, B.-Y. Han, K. McFarland, E. Halkiadakis, Phys. Rev. D, 77, 111301(R) (2008).
- [2] CDF Collaboration, T. Aaltonen *et al.*, Phys. Rev. Lett. 102, 181801 (2009).
- [3] D0 Collaboration, V. M. Abazov *et al.*, Phys. Rev. D 77, 011106 (2008).
- [4] D0 Collaboration, V. M. Abazov *et al.*, Phys. Rev. Lett. 101, 211801 (2008).
- [5] D0 Collaboration, V. M. Abazov *et al.*, 5976-CONF (2009).
- [6] D0 Collaboration, V. M. Abazov *et al.*, Nucl. Instrum. Methods in Phys. Res., Sect. A 565, 463 (2006).
- [7] T. Sjöstrand, S. Mrenna, P. Skands, JHEP 05, 026, (2006).
- [8] S. Agostinelli *et al.*, Nucl. Inst. Meth. A 506 (2003).
- [9] C. Balazs, C.P. Yuan, Phys. Rev. D 56, 5558-5583, (1997).
- [10] P. Nadolsky *et al.*, Phys. Rev. D 78, 013004, (2008).
- [11] E. Barberio, Z. Was, Comput. Phys. Commun. 79, 291 (1994).

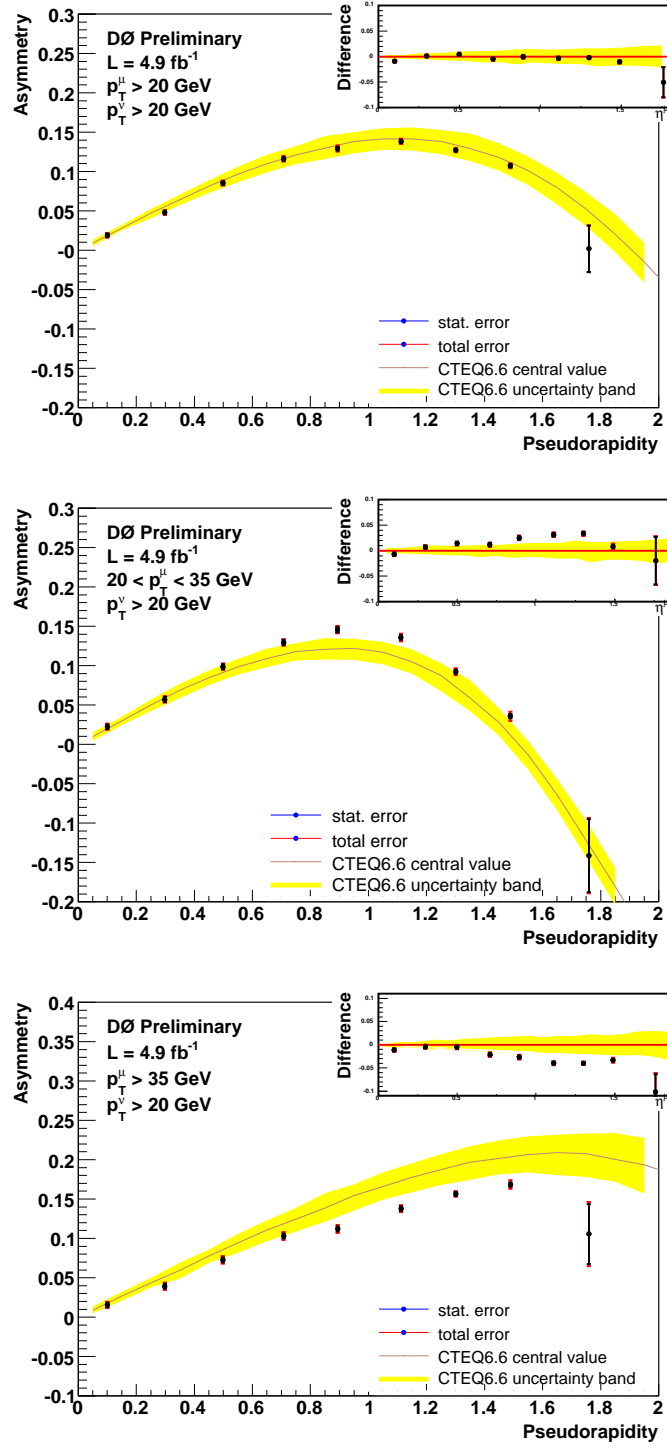


Figure 1. Comparison of the measured $A(\eta)$ with NLO QCD predictions for (top) $p_T^\mu > 20 \text{ GeV}$, (middle) $20 < p_T^\mu < 35 \text{ GeV}$, and (bottom) $p_T^\mu > 35 \text{ GeV}$.